

*Note on Heusler's Magnetic Alloy of Manganese, Aluminium,  
and Copper.*

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In 1903 Fr. Heusler published the discovery of an alloy consisting of manganese, aluminium, and copper, which, in spite of the fact that it contained none of the so-called magnetic metals, iron, nickel, or cobalt, possessed striking magnetic properties. Short accounts of work on the subject by Heusler and some other experimenters appeared,\* but on the whole the discovery seems to have aroused comparatively little interest in this country before August, 1904, when R. A. Hadfield exhibited a specimen of the alloy at the Cambridge meeting of the British Association.

At the beginning of the winter session 1904 an attempt was made to obtain some of this alloy for the Physical Laboratory of Glasgow University, with the view of determining magnetic curves for the material, and of otherwise extending our knowledge of this interesting manganese bronze.

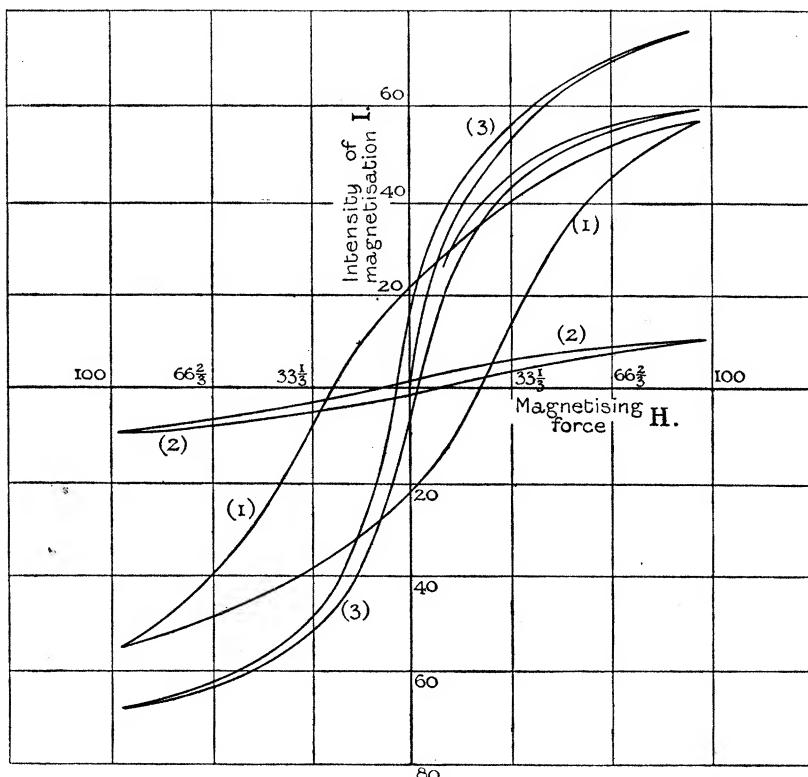
The publication of a paper by Fleming and Hadfield † to a certain extent supplied the information sought, but also served to emphasise the fact that various samples of this alloy possess very different magnetic properties. The maximum induction obtained by Fleming and Hadfield under a field of 200 C.G.S. units is less than one-half that obtained with a field of 150 in the case of one of Heusler's numerous samples. The form of the curves obtained by Fleming and Hadfield must also differ considerably from many of those indicated by the numbers given in Heusler's papers. Under these circumstances it has been decided to continue the work begun here, and to give now a short account of the work so far performed.

Dr. C. E. Fawsitt, of the Chemical Department of the University, became interested in the proposed research and attempted to make samples of the alloy. The apparatus at his disposal, however, did not admit of production of the alloy in anything but small quantities. The specimens obtained proved very retentive of magnetism, but were not suitable for the carrying out of quantitative work. In the meantime two rods of the alloy had been obtained from Herr Heusler by Dr. G. E. Allan, one of the research students in the Physical Laboratory. These rods were ground truly cylindrical on emery and

\* Cf. 'Science Abstracts,' Nos. 622, 623, 636 (1904).

† 'Roy. Soc. Proc.,' June, 1905.

tested by the magnetometric method. The intensity of magnetisation ( $I$ ) was calculated on the assumption that the effective lengths of the specimens were five-sixths of the actual lengths, and the magnetising field ( $H$ ) was corrected by using the demagnetising factors for cylindrical rods given by Du Bois.



The first of the specimens contained about 26.5 per cent. manganese, 14.6 per cent. aluminium, and the remainder copper. This rod so far has only been tested in low magnetic fields; the intensity of magnetisation induced by a field of about 8 C.G.S. units was approximately 105.

The second rod obtained from Herr Heusler contained about 16 per cent. manganese, 8 per cent. aluminium, a little lead, and the remainder copper. After having been dressed, this rod was found to be practically non-magnetic (much less magnetic than is indicated by Curve 2 of the diagram). As it was said to be from the same pouring as another which showed well-marked magnetic qualities, it was conjectured that the heating and vibration to which the rod had been subjected during the dressing operations had destroyed the magnetic quality, and an attempt was made to restore the magnetic properties by thermal treatment. The rod was heated to 400° C. in

a furnace and allowed to cool slowly. After having been placed in a magnetic field it was found to retain a considerable amount of magnetism. It was next heated to 340° C. for about 20 minutes and allowed to cool, when it was found that the magnetic properties were much more pronounced. With the specimen in this state it was put through a cycle of magnetisation, and the results are shown in Curve 1 of the diagram.

It was now decided to try the effect of extremely low temperature upon the material. The specimen was immersed in liquid air, withdrawn, and put through a magnetic cycle as quickly as possible, the specimen warming up somewhat meanwhile. The effect produced was extremely slight, but was towards an increase in magnetic susceptibility.

An endeavour was next made to get the specimen into a better magnetic condition by heating to various temperatures,\* but no improvement was obtained. Incidentally the critical temperature was found to be about 350° C.

An attempt was now made to destroy the magnetic quality of the material. Vigorous tapping at the temperature of the room was found to have no effect upon the residual magnetism. Previous tapping at the temperature of 100° C. had been found to produce a considerable reduction in the residual magnetism, but the original value was restored by again applying the magnetic field. It was thought that sudden cooling or "quenching" from above the critical temperature might permanently destroy the magnetic quality, and such was found to be the case. The specimen was heated to 400° C. in the furnace and then plunged vertically into cold water. Curve 2 of the diagram, which exhibits the results of a magnetic cycle carried through with the specimen after this treatment, shows the alloy to be in a comparatively non-magnetic condition. An examination of the specimen showed it to have several cracks distributed over its surface as a result of the quenching, and this probably affected the magnetic tests to a certain extent.

The effect produced by the temperature of liquid air upon the material in its quenched and, at ordinary temperatures, nearly non-magnetic condition was now investigated and found to be very remarkable. When tested at the temperature of liquid air the specimen was found to be more susceptible to magnetism than in its previous best condition, while it exhibited very much less hysteresis and retentiveness. Curve 3 of the diagram illustrates the new magnetic condition and shows how, moreover, the comparatively high susceptibility thus given to the alloy disappeared as the temperature rose. Curve 2 of the diagram was repeated after the temperature of the specimen had again become normal.

\* Reference should be made to the extensive thermal experiments carried out by Heusler and his collaborators.

A microscopic examination of the material which we have been considering has been made. After many trials it was found that a solution of ammonium hydrate formed an efficient etching agent; the structure of the alloy, which had been revealed by polishing alone, was well brought out by this agent.

The work described here was carried out in the main by Dr. J. Muir and Mr. J. G. Gray, B.Sc., two of my assistants. We have now obtained a considerable quantity of the alloy in the form of rings and rods. These specimens have been cast for us by Messrs. Steven and Struthers, the well-known Glasgow engineers and brass-founders, and some of them are being turned into elongated ellipsoids of revolution. A continuation of the research on the lines indicated is in progress.

[*Addition, January 15, 1906.*—Curves analogous to 1, 2, 3 of the diagram have been obtained from specimens of nickel and steel. In the case of nickel the three curves differed only very slightly. On the steel specimen quenching had, of course, a considerable hardening effect; but the new magnetic condition was only slightly changed when the specimen was brought to the temperature of liquid air.]

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